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APPARATUS FOR DETECTING OPTICAL POSITIONAL DEVIATION

5 This application claims the benefit of Japanese
Patent application No. 2000-208634 which is hereby
incorporated by reference.

BACKGROUND OF THE INVENTION

10 Field of the Invention

 The present invention relates to an optical
positional deviation detecting apparatus used for
optically detecting a positional deviation (an
alignment positional deviation) of a second mark
15 (e.g., a resist mark) with respect to a first mark
 (e.g., a base mark) of a measurement mark (an
alignment mark) formed on a substrate to be inspected
such as a semiconductor wafer etc in a
photolithography manufacturing process etc of a
20 semiconductor wafer.

Related Background Art

 A resist pattern is formed on a wafer at some
separate stages in a photolithography manufacturing
process defined as one of processes of manufacturing
25 a semiconductor chip. To be specific, a
predetermined resist pattern is formed in alignment
on an already-formed pattern (which is called a base

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pattern) at each stage. It is, however, required at every stage that a positional deviation in alignment of the resist pattern with respect to the base pattern be detected and measured. There has hitherto been known an apparatus for detecting this positional deviation in alignment (see, for example, Japanese Patent Application Laid-Open No. 2000-77295). The measurement of the positional deviation in alignment, in which a measurement mark is configured by forming a resist mark on a base mark formed on the substrate when forming the resist pattern, involves the use of an optical positional deviation detecting apparatus (an alignment positional deviation detecting apparatus). In this optical positional deviation detecting apparatus, the measurement mark is irradiated with beams of irradiation, a CCD camera etc photographs an image of the measurement mark from the reflected beams therefrom, then the photographed image is subjected to image processing, and a positional deviation quantity in alignment of the resist mark with respect to the base mark is measured.

By the way, in the case of optically measuring the positional deviation in alignment as described above, it is inevitable that an optical aberration occurs in a measurement optical system (including, namely, an irradiation optical system for irradiating the measurement mark with the beams of irradiation,

and a converging optical system for converging the reflected beams from the measurement mark to form an image of this measurement mark). If this kind of aberration, particularly, an aberration that is rotationally asymmetric with respect to the optical axis exists in a measurement image field area, there occurs a measurement error TIS (Tool Induced Shift) of a measurement value of the alignment positional deviation. A quantity of the rotationally asymmetric aberration, which may be a factor of causing the measurement error TIS, changes depending on the measurement image field area. It is therefore required to set such a measurement image field area that the quantity of the rotationally asymmetric aberration is minimized.

As for the measurement image field area, in terms of the measurement error, an optimum image field area might differ depending on elements of the measurement mark (for instance, a height of the resist mark of the measurement mark, a height or depth of the base, a reflectivity, a size and so forth). Hence, even if in the same measurement optical system, it is required that the image field area be adjusted optimal with respect to each of many elements of the measurement mark, and the problem is that the adjustment of the image field area is difficult and time-consuming.

SUMMARY OF THE INVENTION

It is a primary object of the present invention, which was devised to obviate the above problem, to provide an optical positional deviation detecting apparatus capable of searching and setting a common image field area optimal to any kind of measurement mark, and having such a construction as to eliminate an adjustment of the image field area for each element of the measurement mark.

To accomplish the above object, according to one aspect of the present invention, an optical positional deviation detecting apparatus comprises an irradiation optical system for irradiating a measurement mark configured by forming a second mark (e.g., a resist mark) on a first mark (e.g., a base mark) with a beam of irradiation, an image forming optical system for forming an image of the measurement mark by converging reflected beam from the measurement mark, an imaging device for photographing the image of the measurement mark, which has been formed by the image forming optical system, an image processing device for measuring the positional deviation in alignment of the second mark with respect to the first mark by processing an image signal obtained by the imaging device, and an image field area adjustment mechanism for adjusting an image field area for the imaging device to photograph

the image of the measurement mark.

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The image field area adjustment mechanism is constructed of a field stop provided on the irradiation optical system, a field stop position adjustment mechanism for adjusting a position of the field stop, and an imaging position adjustment mechanism for adjusting a position of the imaging device. The field stop and an imaging surface of the imaging device are disposed in optically conjugate positions. The imaging position adjustment mechanism adjusts the position of the imaging device in accordance with the field stop positional adjustment effected by the field stop position adjustment mechanism. The image field area used when imaging the measurement mark can be thereby set to an optimum area within all the image field areas embraced by the measurement optical system.

In the case of optically detecting the positional deviation in alignment between the first mark and the second mark of the measurement mark by use of the thus constructed optical positional deviation detecting apparatus, the image field area adjustment mechanism is capable of presetting the image field area where the imaging device images the measurement mark, to an area where the measurement error TIS is always minimized regardless of the elements of the measurement mark within all the image

field areas embraced by the measurement optical system. If the optimum image field area is thus preset, the alignment positional deviation can be measured by use of the thus set visual field
5 irrespective of the elements of the measurement mark, and the highly efficient adjustment can be made.

It is therefore preferable that the image field area adjustment mechanism adjusts the image field area on the basis of the asymmetric focus
10 characteristic curve of the L/S mark pattern image obtained when the L/S mark pattern image is formed within the image field area of the imaging device. Further, it is also preferable that the image field area adjustment mechanism adjusts the image field
15 area so that the asymmetric focus characteristic curve of the L/S mark pattern image obtained when the L/S mark pattern image is formed within the image field area of the imaging device, exhibits a characteristic that is symmetric to the center of the
20 visual field.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a view schematically showing a construction of an optical positional deviation
25 detecting apparatus according to the present invention;

FIGS. 2A and 2B are a plan view and a sectional

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view each showing a measurement mark used for optically detecting the positional deviation;

FIGS. 3A and 3B are plan views showing the measurement mark in a position of zero degree and a position when rotated through 180 degrees.

FIGS. 4A and 4B are a plan view and a sectional view each showing an L/S mark pattern used for adjusting an image field area; and FIG. 4C is a graph showing a profile of an image signal intensity of the L/S mark image pattern;

FIG. 5 is a graph showing QZ curves with respect to the whole of the L/S mark image pattern;

FIGS. 6A, 6B and 6C are graphs showing the QZ curves in left, central and right areas with respect to the L/S mark image pattern; and

FIGS. 7A, 7B and 7C are graphs showing the QZ curves in the left, central and right areas with respect to the L/S mark image pattern.

20 DESCRIPTION OF THE PREFERRED EMBODIMENT

A preferred embodiment of the present invention will hereinafter be described with reference to the accompanying drawings. FIG. 1 shows one example of an apparatus for measuring an optical positional deviation according to the present invention. Note that a direction perpendicular to a sheet surface is set as an X-axis direction, directions extending to

the right and left sides are set as Y-directions, and directions extending up and down are set as Z-directions for a simplicity of the explanation.

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This measuring apparatus measures a positional deviation in alignment of a resist mark from a measurement mark 52 formed on a wafer 51. When measuring the positional deviation, the wafer 51 is placed on a stage 50 so constructed as to be rotatable and movable horizontally (movable in X-Y directions) and also movable up and down (movable in Z-directions). The measuring mark 52 is configured by forming, when a predetermined resist pattern is formed on a base pattern of the wafer 51 by a photolithography process, as shown in, e.g., FIGS. 2A and 2B, a rectangular resist mark 54 on the rectangular base mark 53 formed along the side end of the wafer 51. The optical positional deviation measuring apparatus according to the present invention measures a positional deviation in alignment of the resist mark 54 with respect to the base mark 53.

This optical positional deviation measuring apparatus includes an irradiation optical system 10 for irradiating the measuring mark 52 with a beam of irradiation, an image forming optical system 20 for forming an image of the measuring mark by converging a beam reflected from the measuring mark, an imaging

device 30 for photographing the image of the measuring mark with its image thus formed, and an image processing device 35 for processing an image signal obtained from the imaging device 30.

5 To start with, the irradiation optical system 10 includes an irradiation source 11, an irradiation aperture stop 12 and a condenser lens 13. The beam of irradiation emitted from the irradiation source 11 is stopped down to a given size (diameter) of beam by the irradiation aperture stop 12, and inputted to and converged by the condenser lens 13. A field stop 14 is irradiated with the irradiation beam converged by the condenser lens 13. The field stop 14 has a rectangular field stop aperture S1 defined by a hatching area in FIG. 1. The field stop 14 so supported by a field stop position adjusting mechanism 40 as to be movable in the X-Z directions (i.e., the field stop 14 is movable within a plane extending up and down in the direction perpendicular to the sheet surface).

20 The irradiation beam emitted and penetrating the field stop aperture S1 of the field stop 14, falls upon a radiation relay lens 15 and is collimated into a parallel beam by this radiation relay lens 15. The thus collimated beam is incident upon a half prism 16. The irradiation beam reflected by the half prism 16 exits downward and is converged

by a first objective lens 17. The converged beam falls vertically upon the measuring mark 52 disposed on the wafer 51. Herein, the field stop 14 and the measuring mark 52 are disposed in positions
5 conjugated with each other in the irradiation optical system 10. The measuring mark 52 on the wafer 51 is irradiated with the irradiation beam taking a shape corresponding to the rectangular shape of the field stop aperture S1.

10 The reflected beam exiting after the irradiation beam has thus fallen upon the surface of the wafer 51 including the measuring mark 52, is led via the image forming optical system 20 to the imaging device 30. To be specific, the reflected beam
15 is collimated into a parallel beam by the first objective lens 17 and, after passing through the half prism 16, forms an image of the measuring mark 52 on a primary image forming surface 28 by a second objective lens 21 disposed above the half prism 16.
20 Further, the beam penetrates a first image forming relay lens 22 and stopped down to a given size of beam by an image forming aperture stop 23, and forms an image of the measuring mark 52 on a secondary image forming surface 29 by a second image forming
25 relay lens 24.

The CCD camera (the imaging device) 30 is disposed so that the secondary image forming surface

29 becomes coincident with an imaging surface 31. The CCD camera 30 photographs an image of the measuring mark 52. Then, an image signal obtained by the CCD camera 30 is sent to the image processing device 35, wherein the image signal is processed as will be described later on. As can be known from this arrangement, the measuring mark 52 and the imaging surface 31 have a conjugate positional relationship. Note that the CCD camera 30 is so supported by an imaging position adjustment mechanism 45 as to be movable in the X-Y directions (i.e., movable within a plane extending in the right-and-left directions perpendicular to the sheet surface).

The measuring mark 52, as shown in FIGS. 2A and 2B, consists of the base mark 53 taking a rectangular recessed configuration formed on the surface of the wafer 51, and the resist mark 54 formed on the base mark 53 simultaneously when forming a resist pattern in the photolithography manufacturing process. A setting in the photolithography manufacturing process is that the resist mark 54 is formed in a central position of the base mark 53, and a quantity of positional deviation of the resist mark 54 with respect to the base mark 53 corresponds to a quantity of positional deviation in alignment of the resist pattern with respect to a base pattern. Therefore, as shown in FIG. 2A, the optical positional deviation

detecting apparatus having the construction described above measures an interval R between a central line C1 of the base mark 53 and a central line C2 of the resist mark 54 as an optical positional deviation in alignment. Note that the alignment positional deviation quantity R shown in FIG. 2A is defined as a positional deviation quantity in the Y-axis direction (the lateral direction), however, a positional deviation quantity in the direction orthogonal to the Y-axis direction, i.e., in the X-axis direction (the vertical direction) is likewise measured.

When thus measuring the alignment positional deviation quantity R of the measuring mark 52, if there exists an aberration, particularly, a rotationally asymmetric aberration in the measuring optical system (i.e., the irradiation optical system 10 and the image forming optical system 20), a problem arises, wherein a measured value of the alignment positional deviation quantity R contains a measurement error TIS. This measurement error TIS will be briefly explained. This measurement is, as shown in FIGS. 3A and 3B, executed in two directions where the measuring mark 52 is positioned at zero degree and rotated through 180 degrees. That is, at first, as shown in FIG. 3A, an alignment positional deviation quantity R_0 of the resist mark 54 with respect to the base mark 53 is measured in a state

where an imaginary position mark 53a is positioned on the left side. Next, as shown in FIG. 3B, an alignment positional deviation quantity R_{180} is measured in a state where the imaginary position mark 53a is positioned on the right side by rotating the measuring mark 52 through 180 degrees. Then, the measurement error TIS is calculated in the following formula (1):

$$TIS = (R_0 + R_{180}) / 2 \quad \dots (1)$$

As known from the formula (1), even if there is an alignment positional deviation of the resist mark 54 with respect to the base mark 53, the measurement error TIS calculated by the formula (1) to theoretically becomes zero. If an optical aberration, particularly, a rotationally asymmetric aberration exists in the measurement optical system, however, even in the case of rotating the measuring mark 52 through 180 degrees, this does not mean that this aberration is rotated. Hence, a value corresponding to only an influence of the aberration is obtained as the measurement error TIS from a result of the calculation in the formula (1).

If the alignment positional deviation quantity R is measured by the optical positional deviation measuring apparatus while containing the measurement error TIS occurred due to the optical aberration described above, a precise alignment positional

deviation quantity R can not be measured. Therefore, the optical positional deviation measuring apparatus of the present invention makes such an image field area adjustment as to restrain the influence of the measurement error TIS to the greatest possible degree. This will be touched in the following discussion.

The image field area is adjusted by placing on the stage 50 a wafer formed with an L/S mark pattern 60 taking a configuration as shown in FIGS. 4A and 4B as a substitute for the wafer 51 in the apparatus shown in FIG. 1, and processing an image of the L/S mark photographed by the CCD camera 30, which involves irradiating the L/S mark pattern 60 with the beam from the irradiation optical system 11. This L/S mark pattern 60 is, as shown in FIGS. 4A and 4B, composed of a plurality of linear marks 61 ~ 67 each having a line width of $3 \mu\text{m}$, a recessed depth of $0.085 \mu\text{m}$ (equivalent to $1/8$ of an irradiation beam λ) and extending in parallel with each other at a pitch of $6 \mu\text{m}$.

The image processing device 35 processes the image of the L/S mark pattern photographed by the CCD camera 30, thereby obtaining an intensity of the image signal. A profile of the intensity becomes as shown in FIG. 4C. Herein, though the signal intensity decreases in the recessed positions of the linear marks 61 ~ 67, a signal intensity difference Δ

I in the recessed positions on both right and left sides of every linear mark, is obtained, and these signal intensity differences ΔI of all the linear marks 61 ~ 67 are averaged, thereby obtaining a value
5 Q ($Q = 1/7 \times \sum (\Delta I/I)$) representing an asymmetry of the L/S mark pattern image. Next, the L/S mark pattern 60 is moved in the Z-direction by moving the stage 50 in the up-and-down direction (the Z-direction, and the value Q is obtained per height
10 position (the position in the Z-direction), thus obtaining a focus characteristic of the value Q. This focus characteristic is expressed by, for instance, QZ curves as shown in FIG. 5.

FIG. 5 shows two types of QZ curves, i.e., a
15 QZ curve (1) and a QZ curve (2). The QZ curve (1) shows a large rotationally asymmetric aberration, while the QZ curve (2) shows a small rotationally asymmetric aberration. It may therefore be considered that such an adjustment as to exhibit the
20 QZ curve (2) be made.

The following is a brief explanation of this kind of adjustment (which may be called a QZ adjustment). A shape of the QZ curve is determined by a telecentricity of radiation (a tilt of the
25 irradiation beam), an eclipse of the image forming beam, an eccentric coma aberration and so on. Hence, the QZ adjustment involves adjusting the

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telecentricity of radiation (the tilt of the irradiation beam) by adjusting the X- and Z-axis directional positions of the irradiation aperture stop 12, and the eclipse of the image forming beam is adjusted by adjusting the X- and Z-axis directional positions of the image forming aperture stop 23. Moreover, the eccentric coma aberration is corrected by making an eccentric movement of the whole or a part of the lens system of the lenses 21, 22 in the direction perpendicular to the optical axis. The details of the QZ adjustment are disclosed in Japanese Patent Application Laid-Open No. 2000-77295.

According to the present invention, the image field area adjustment is performed in the way that follows. To begin with, the whole L/S mark pattern shown in FIGS. 4A and 4B is adjusted based on the QZ adjusting method so that the focus characteristic changes from the state of the QZ curve (1) to the state of the QZ curve (2) shown in FIG. 5. Next, the linear marks 61 ~ 67 configuring the L/S mark pattern 60 shown in FIGS. 4A and 4B are divided into a group of the left area linear marks 61 ~ 63 each positioned within a left area L, a group of central area linear marks 63 ~ 65 each positioned within a central area C, and a right area linear marks 65 ~ 67 each positioned within a right area R. Then, a value Q is obtained by averaging the signal intensity differences ΔI of

the linear marks existing in each of these areas, and QZ curves in the respective areas are obtained as shown in FIGS. 6A - 6C. Note that FIGS. 6A - 6C each show one example of the thus obtained QZ curve in each area. In this case, the rotationally asymmetric aberration is large in the left area L and small both in the central area C and in the right area R. The QZ curves shown in FIGS. 6A - 6C are displayed by a monitor.

The CCD camera 30 photographs an image of the measuring mark 52 by use of the visual fields areas exhibiting the characteristics shown in FIGS. 6A - 6C, and the alignment positional deviation quantity R of the resist mark 54 with respect to the base mark 53, is measured. In this case, it must be inevitable that the measurement error TIS calculated by the formula (1) occurs, and it is difficult to obtain the accurate alignment positional deviation quantity R.

Therefore, next, the field stop position adjustment mechanism 40 adjusts the position of the field stop 14, and the field area in the measurement optical system is changed. Note that the positions of the L/S mark pattern 60 and of the CCD camera 30, which are optically conjugate to the field stop 14, are adjusted by the imaging position adjustment mechanism 45 with the aid of the stage 50, corresponding to this positional adjustment of the

field stop 14. Then, in a state where the field area adjustment has been thus done, the QZ adjustment described above is again performed. Thereafter, the QZ curves in the left, central and right areas L, C and R are obtained in the same way as the above. Such field area adjustment may be conducted by an operation observing the display on the monitor or automatically.

There is searched such a field area that each of the QZ curves in the left, central and right areas L, C and R, which have been obtained by changing the field area, comes to show a lateral symmetry with respect to the center of the visual field as shown in FIGS. 7A - 7C. Then, the alignment positional deviation of the measuring mark 52 is measured by this field area. in the case of such a field area that the QZ curves of the L/S mark pattern image exhibit the characteristics as shown in FIGS. 7A- 7C, for instance, even when rotating the L/S mark pattern 60 through 180 degrees, the characteristics are optically much the same because the QZ curves in the right and left areas are symmetric. The QZ curves shown in FIGS. 7A - 7C are displayed by the monitor.

Therefore, the CCD camera 30 photographs the image of the measuring the mark 52 in this field area, and the alignment positional deviation quantity R of the resist mark 54 with respect to the base mark 53,

is measured. Then, an error based on the rotationally asymmetric aberration contained in the alignment positional deviation quantity R_0 and an error based on the rotationally asymmetric aberration contained in the alignment positional deviation quantity R_{180} , are cancelled each other in the calculation by the formula (1), resulting in an extremely small measurement error TIS. The accurate alignment positional deviation quantity R can be thereby obtained. Thus, there is set such a field area that the error based on the rotationally asymmetric aberration contained in the alignment positional deviation quantity R_0 and the error based on the rotationally asymmetric aberration contained in the alignment positional deviation quantity R_{180} , are cancelled each other in the calculation by the formula (1), whereby the alignment positional deviation quantity can be always precisely measured irrespective of the elements of the measurement mark.

As discussed above, according to the present invention, when optically detecting the alignment positional deviation of the second mark (the resist mark) with respect to the first mark (the base mark) of the measurement mark, the image field area adjustment mechanism is capable of presetting the image field area where the imaging device images the measurement mark, to an area where the measurement

error TIS is always minimized regardless of the elements of the measurement mark within all the image field areas embraced by the measurement optical system. If the optimum image field area is thus
5 preset, the alignment positional deviation can be measured by use of the thus set visual field irrespective of the elements of the measurement mark, and the highly efficient adjustment can be made.

It is therefore preferable that the image field
10 area adjustment mechanism adjusts the image field area on the basis of the asymmetric focus characteristic curve of the L/S mark pattern image obtained when the L/S mark pattern image is formed within the image field area of the imaging device.
15 Further, it is also preferable that the image field area adjustment mechanism adjusts the image field area so that the asymmetric focus characteristic curve of the L/S mark pattern image obtained when the L/S mark pattern image is formed within the image
20 field area of the imaging device, exhibits a characteristic that is symmetric to the center of the visual field.

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